INTRODUCTION

The principal source of freshwater in southeast Florida is the surficial aquifer system. The Biscayne aquifer, the major and only formally named aquifer of this system, is a highly permeable limestone and sandstone unit that occurs at or near land surface in most of Broward County (Parker and others, 1955). In Broward County, unnamed hydrogeologic units of low to relatively high permeability were penetrated below the Biscayne aquifer and laterally where it pinches out. These unnamed hydrogeologic units are hydrologically contiguous with the Biscayne aquifer and, together, they constitute the surficial aquifer system. The base of the surficial aquifer system is delineated at the top of a thick sequence of a relatively impermeable clay and silt unit in the lower part of the Tamiami Formation or in the Hawthorn Formation.

This report describes the geologic framework of the surficial aquifer system in Broward County, Fla. (fig. 1). It is part of a long-term intensive study begun by the U.S. Geological Survey in 1979, in cooperation with the South Florida Water Management District, to describe the geology, hydrologic characteristics, and the ground-water quality of the surficial aquifer system in southeast Florida. Twenty-seven test wells were drilled completely through the surficial aquifer system and into the underlying, relatively impermeable, units of the Hawthorn Formation to obtain the data needed to describe the geology of the surficial aquifer system. The test wells were drilled by the reverse air, dual wall method. This method provided geologic samples superior to those obtained by most other methods in that the samples were uncontaminated by drilling fluid and were large enough for describing sedimentary and petrographic characteristics. Detailed lithologic logs were made from rock cuttings and cores obtained from these wells and are presented in this report. These logs were used to prepare geologic sections that show the lithologic variations, thickness of the lithologic units, and different geologic formations that comprise the aquifer system.

METHODS

The lithologic logs were made from microscopic examination of the well cuttings and cores collected during the drilling phase. Other methods, such as stains, dilute hydrochloric acid tests, and petrographic thin sections, were used when additional aid in identifying and describing the sample was needed. Folk's 1962 classification of carbonate rocks was used in classifying rocks with a calcium carbonate content of 50 percent and greater (Folk, 1968). The standard Wentworth terrigenous grain-size classification (Pettijohn, 1957, p. 27) was used in classifying sediments and rocks consisting of less than 50 percent calcium carbonate. A modifying term was added to the description of the terrigenous samples if a foreign size content greater than 10 percent was present. A silty sand contains over 10 percent silt, a clayey silt contains over 10 percent clay, and a sandy clay contains over 10 percent sand. The same principle was utilized for carbonate rocks, so that a sandy limestone contains more than 10 percent sand. The percentage of a given constituent was determined by using the "Comparison Chart for Visual Percentage of Estimation" from Terry and Chilingar (in p. x). The constituent rock fragments (RF) found in some samples are noted in the lithologic descriptions in the abbreviated form RF. The colors indicated by the chart numbers in parenthesis are based on the "Rock-Color Chart" by Goddard and others (1948) and were assigned while the samples were damp.

GEOLOGY The surficial aquifer system in Broward County is composed of limestone,

sandstone, sand, shell, limemud, silt, clay, and an admixture of these materials.

These sediments were deposited during the Pliocene through Pleistocene Epochs

(Parker and others, 1955, p. 160) and were assigned to the following general stratigraphic sequence from bottom to top, however, some units are equivalent: Tamiami Formation, Caloosahatchee Marl, Fort Thompson Formation, Key Largo Limestone, Anastasia Formation, Miami Oolite, and Pamlico Sand. The Caloosahatchee Marl occurs as erosional remnants in southeast Florida; in Broward County (Schroeder and others, 1958, p. 11), it has been reported only in the extreme northwestern part of the county. The Caloosahatchee Marl was not encountered in any well drilled during the present study.

The geologic sections A-A' to D-D' on sheets 1 and 2 show some of the variations in the wedge of sediments that make up the framework of the surficial aquifer system. The aquifer system is thickest along the coast where in some areas it may exceed 400 feet in thickness and gradually thins inland toward the west and southwest where it is about 160 feet thick. The aquifer system is comprised of distinct lithologic units that show numerous facies changes that were brought about primarily by changes in sea level. A distinct contrast exists in lithologies between western and eastern Broward County defined, respectively,

prised of distinct lithologic units that show numerous facies changes that were brought about primarily by changes in sea level. A distinct contrast exists in lithologies between western and eastern Broward County defined, respectively, as the area west of and under the water conservation areas and the area east of U.S. Highway 441 (fig. 1). In the western part of the county, the aquifer system is primarily composed of limestone, sand, limemud, and clay, but the eastern part is primarily composed of sandstone, sand, sandy limestone, and silt (see sheets 1 and 2, sections A-A' to D-D'). The transition between the predominantly carbonate and predominantly clastic areas lies between the water conservation areas and U.S. Highway 441.

The uppermost lithologic unit of the aquifer system in western Broward County usually consists of pale-orange to yellowish-brown, mottled, well-cemented limestone that contains abundant specimens of the freshwater gastropod

limestone that contains abundant specimens of the freshwater gastropod *Helisoma* sp. and has undergone diagnesis as a result of prolonged contact with slowly moving water. The limestone exhibits features of dissolution, replacement, and reprecipitation of calcite as cavity-filling cement. Iron oxide stains and calcrete crust indicate that the limestone has been subaerially exposed. This limestone unit ranges in thickness from about 4 to 72 feet and is thickest along the south-central part of the county, feathering out toward the easternmost edge of the water conservation areas in the vicinity of wells G-2322 (section C-C') and G-2341 (section B-B'). In places, lenses of shelly sandy micrite (limemud) and shelly micritic sand containing many specimens of *Chione cancellata* and *Turritella* sp. are interbedded with the limestone unit. The physical characteristics and faunal assemblage of this limestone are similar to the limestone units of the Fort Thompson Formation, as described by Schroeder and others (1958,

p. 12-13).

A partially cemented, sandy, shelly, gray limestone lies unconformably below the upper unit. It contains a faunal assemblage that is abundant in pelecypods (*Pecten* sp. and *Ostrea* sp.), pink barnacles, and echinoids. The faunal assemblage, color, and other physical properties of this limestone are similar to the limestone prototype of the Tamiami Formation in Collier County, as described by Parker and others (1955, p. 85), and the limestone is probably equivalent in age. This gray limestone makes up most of the surficial aquifer system in western Broward County, and it decreases in thickness toward the east where it interfingers with sand, shelly sand, and sandstone or grades into a loosely cemented, shelly sandstone containing detrital carbonate. Local thin lenses of shelly clayey sand, shells, and micrite interfinger with the gray limestone in the western part of

The gray limestone is underlain by fine to very fine grained quartz sand which contains phosphorite as an accessory mineral. The sand is shelly in many places; the shells are comparable in age to those in the overlying limestone and to those in the sand unit of the Tamiami Formation. With increasing depth, the silt and clay content of the fine-sand unit increases, and the unit grades into clay. Parker and Cooke (1944, p. 96-112) assigned this clay to the Hawthorn Formation. The clay is slightly calcareous and grades into clayey silt and silt toward the east where it was over 300 feet below land surface in test well G-2345 (sheet 1, section C-C'; sheet 2, section G-G'). In many of the wells drilled, it was difficult to differentiate between the Tamiami silt and the Hawthorn silt without a detailed foraminferal study. In these wells, the symbol "Tth" was used for Tamiami Formation and Hawthorn Formation undifferentiated. The silt and clay unit was not penetrated in test wells near the coast, two of which were drilled to a maximum depth of 476 feet below land surface (sheet 2, section H-H'). Apparently, the silt and clay unit grades laterally into impure Hawthorn limestone in this

The part of the surficial aquifer system that extends from the coast to the eastern edge of the water conservation areas primarily consists of beach and inner shelf deposits such as sand, sandstone, and sandy shelly limestone. The uppermost part of the surficial aquifer system throughout that part of Broward County consists of a pale-orange to brown quartz sand that ranges from very coarse to very fine grained but is moderately to well sorted toward the medium sand-size fraction. This sand ranges in thickness from a minimum of 5 feet to a maximum of 52 feet in the vicinity of well G-2327 (sheet 2, sections D-D' and G-G'). This sand was called the Pamlico Sand by Parker and Cooke (1944,

In test well G-2347 (sheet I, section C-C'), a 13-foot thickness of the oolitic and bryozoan limestone facies of the Miami Oolite occurs at land surface. Well G-2347 was the only well drilled during this investigation that penetrated the Miami Oolite. Petrographic thin sections made from this limestone show that fine-grained angular quartz forms the nuclei of the ooids. A 20-foot layer of fine-grained quartz sand lies below the oolitic limestone. The sand grades into clay and limemud toward its base and contains approximately 3 to 10 percent ooids. This sand layer is considered in this report to be a part of the Miami

The Key Largo limestone underlies this sand unit in well G-2347 and also was

penetrated near the coast and southeast Broward County in wells G-2327,

G-2328, and G-2344. The Key Largo is a highly crystalline, reefal limestone deposit that contains corals (including Monastrea sp.), Halimeda fragments, and Below the Pamlico Sand and interfingering with the Key Largo limestone and Miami Oolite in east Broward County are numerous layers and lenses of sand, shelly sand, shelly and nodular sandstone, and sandy limestone. These interbedded materials are part of the Anastasia Formation and are thickest in the northeastern part of the county where the Anastasia Formation is over 180 feet below land surface. The Anastasia Formation thins toward the central and southern parts of the county where it interfingers with the Fort Thompson Formation. Lying unconformably beneath these sediments are thin layers of limestone of the Tamiami Formation (similar to that found in west and central Broward County) interbedded with a sandstone and sand facies of the same formation. These materials are underlain by a relatively impermeable silt unit that is of Miocene age (F.W. Meyer, U.S. Geological Survey, oral commun., 1983) and whose top forms the base of the surficial aquifer system in east Broward County. In the coastal areas (sheet 2, section H-H') instead of the silt unit, there occurs a loosely cemented, pale-green limestone which is probably of Hawthorn age; it

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was encountered at depths ranging from 300 to 480 feet below land surface. The

limestone consists of fossiliferous micrites and intramicrites that are abundant in

mollusks and planktonic foraminifers. This limestone unit is the base of the

aquifer system in the coastal areas (J.E. Fish, U.S. Geological Survey, oral com-

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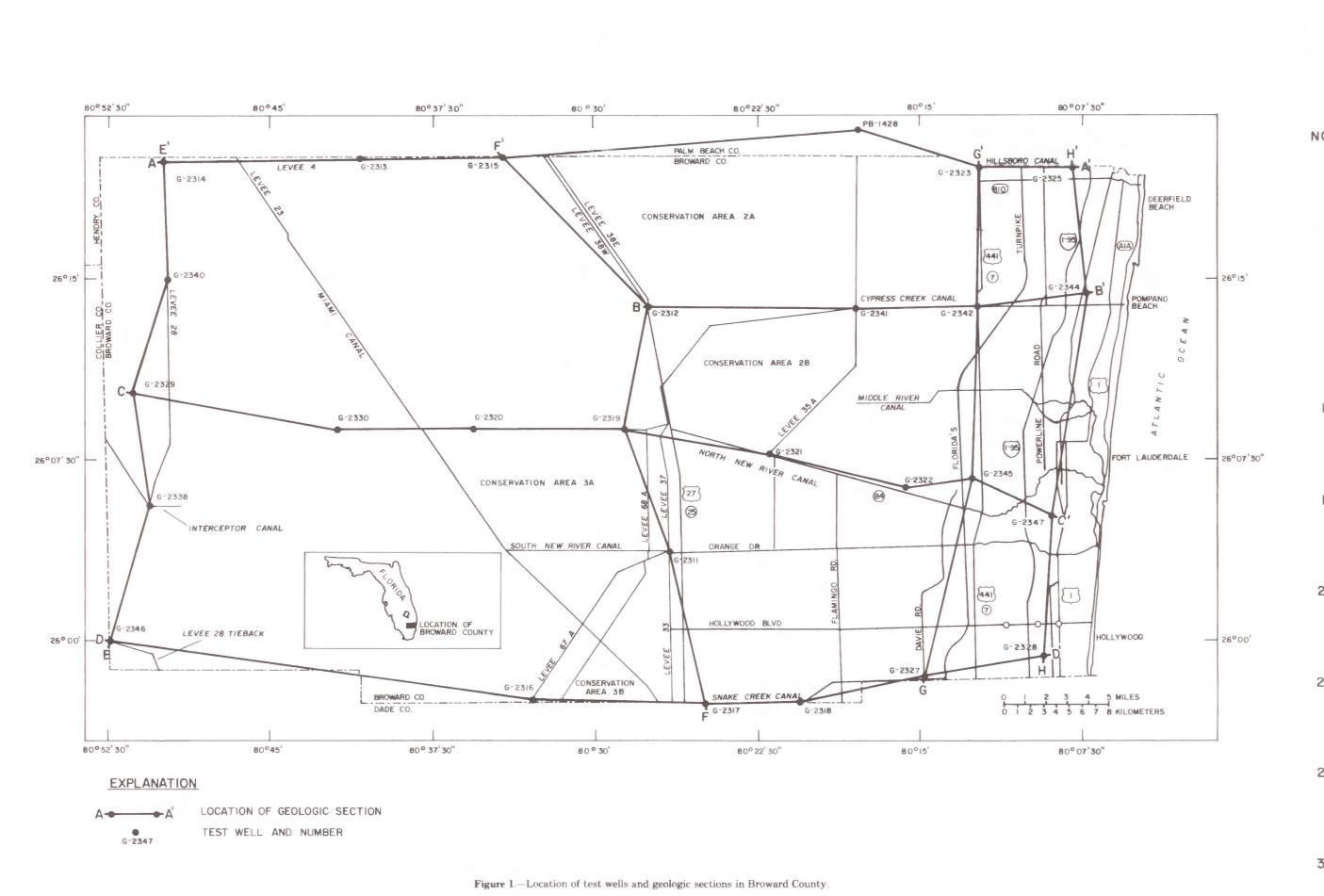
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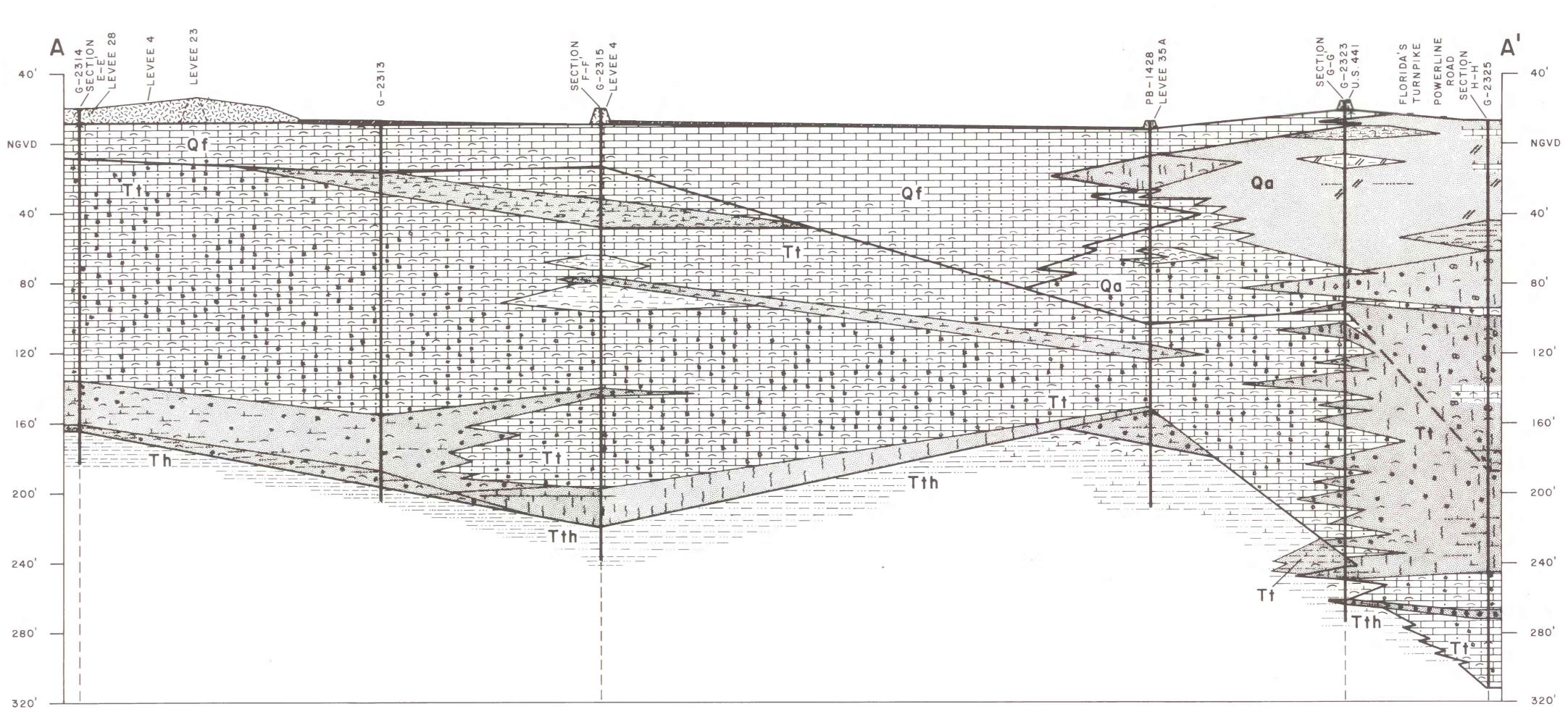
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WEST-EAST SECTION A-A'

